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ORIGINAL RESEARCH

RELIABILITY OF AND THE RELATIONSHIP BETWEEN ULTRASOUND MEASUREMENT AND THREE CLINICAL ASSESSMENTS OF HUMERAL TORSION

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ABSTRACT

Purpose/Background: Differences in humeral torsion have been observed between overhead athletes and non-athletes. Although humeral torsion may be an adaptive process for athletic performance, it may be associated with injury. Methods for measuring humeral torsion have consisted of radiography, computer tomography, and ultrasound imaging. However, diagnostic imaging may be costly and not available to all clinicians. The implementation of clinical assessments may be an alternative way to measure humeral torsion. Before clinical measures can be recommended, these assessments need to be evaluated for validity and reliability of each test. The purpose of this study was to assess the intratester and intertester reliability of three clinical tests, intratester reliability of ultrasound measures, and the validity of each clinical test to ultrasound measures.

Methods: Thirty participants (male: 12, female: 18; age: 20 ± 2 years; height: 174.24 ± 9.35 cm; mass: 70.53 ± 11.06 kg; body mass index: 23.13 ± 2.47 kg/m^2; years in sport: 9 ± 4 years) with experience in overhead sports were assessed for humeral torsion, bilaterally. Humeral torsion was assessed using musculoskeletal ultrasound by a single assessor, and using three separate clinical assessments by two independent assessors. Clinical assessments included the angle of rotation during both the bicipital tuberosity palpation with the shoulder abducted at 90 degrees (Palp90) or 45 degrees (Palp45), and the angle of external rotation during horizontal adduction (HADD).

Results: Intratester reliability for the ultrasound measure was good (ICC = 0.907), along with intratester reliability for both assessors across each clinical assessment (ICC's > 0.769). Poor to moderate reliability was observed between assessors for each clinical assessment (ICC = 0.256 Palp90, ICC = 0.419 Palp45, ICC = 0.243 HADD. Only the Palp90 measure had a fair but significant (r = 0.326, $p = 0.011$) relationship with ultrasound measures.

Conclusion: Individual assessors can achieve reliable ultrasound, bicipital tuberosity palpation and HADD values across multiple trials; however, these measures are not consistent between assessors. Additionally, only one clinical test had a fair but significant relationship with ultrasound measures. Improved testing procedures may be needed to increase between assessor reliability and strength of relationships to ultrasound measures. Current application of clinical assessments to measure humeral torsion is limited.

Level of Evidence: 3b; Grade of Recommendation C

Key Words: athletes, overhead, shoulder

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INTRODUCTION

Osseous adaptations occurring as a result of overhead participation in sports have previously been reported between dominant and non-dominant shoulders[1-12] and when compared to control participants.[2,6,10] This adaptation is a result of the rotation of the humerus between the proximal and distal segments of the bone.[6,13] Increases in humeral torsion may be associated with injuries in the upper extremity in athletes who participate in overhead athletics.[1,10-12,14] The ability to implement an accurate and readily available assessment of humeral torsion could potentially identify individuals at risk for injury. Current measures traditionally used for assessing humeral torsion include computed tomography,[2,7,12,13] radiographs,[1,3,4] and ultrasound (US) imaging.[5,6,8-11,13-15]

Computed tomography (CT) is considered the gold standard for assessment of humeral torsion due to its direct measurement of the humerus.[13] US is an indirect method of measuring humeral torsion by using the bicipital forearm angle.[5,6,15] This measure represents the intersection angle between a line through the top of the bicipital groove when the bicipital tuberosities are even on an US image with a line that corresponds to the axis of the forearm (Figures 1 and 2).[5,15] An inverse relationship exists between the bicipital forearm angle and humeral torsion measurements indicating that a decrease in one measure corresponds to an increase in the other.[5,15] Although US is an indirect measurement of humeral torsion, this method has potential advantages including reduced exposure to radiation[6,13] and the accessibility of a portable US unit.[13] Comparisons between CT and US indicate that a strong relationship between the two measures exists, along with the ability to obtain reliable measures with small measurement errors for each method of assessing humeral torsion.[13]

Clinical assessments have also been described to measure humeral torsion,[6,15] allowing health care professionals to measure humeral torsion without instrumentation or machinery that may be costly, inaccessible, or require a trained technician.[15] Implementing clinical assessments could identify athletes at risk for injury or potentially monitor overhead athletes for changes in humeral torsion measures through the course of a season or career. Palpation methods of the bicipital groove[6] and bicipital tuberosities[15] for humeral torsion take advantage of common skills used by clinicians, but are dependent on clinician skills. A third novel application using the horizontal adduction (HADD) test may be another indirect way to measure humeral torsion clinically. During the resting position of HADD test, the shoulder will have a natural amount of shoulder rotation due to the test positioning. This resting angle during the HADD test might be associated with the amount

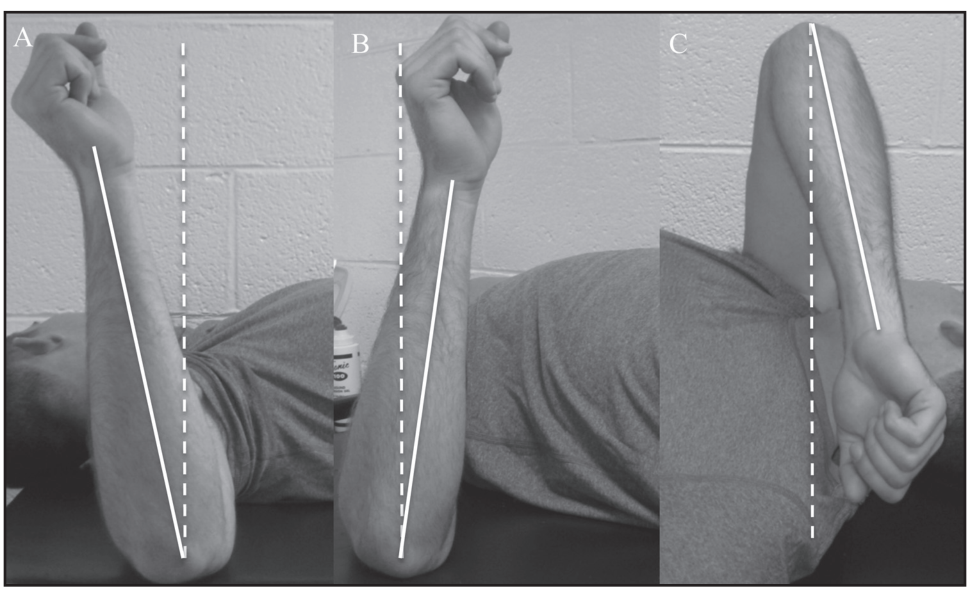

Figure 1. *Positioning and bicipital-forearm angle for the palpation at 90 degrees (A) and palpation at 45 degrees (B). Positioning and angle measured for horizontal adduction (C).*

of osseous adaptations in the humerus. However there is currently limited research to support the use of clinical assessments for measuring humeral torsion.[6,15] Prior to implementing clinical assessments to measure humeral torsion, reliability and validity of these measures should be determined and compared to previously established methods.

The purpose of this study was to assess the intratester and intertester reliability of three clinical tests, intratester reliability of US and compare the validity of each clinical test to US measures of humeral torsion. The authors' hypothesized that both within and between assessor measures for each clinical test will be good and that good relationships will exist between clinical assessments and an US measure of humeral torsion.

METHODS

Subjects were eligible to participate in the current study if they were male or female overhead athletes at the intercollegiate or club level with a minimum of three years of overhead sport participation. Subjects were excluded from participation if they self reported an acute shoulder injury, inability to tolerate the testing positions or any visible open wounds or skin infections at the site of palpation or transducer placement. All participants interested in the current study that met the above inclusion criteria provided written informed consent approved by the university review board before participation in the study and were given a brief description of the study procedures prior to testing.

Range of Motion

Participants were positioned supine with the shoulder abducted 90 degrees and elbow flexed at 90 degrees with the palm pronated for range of motion measures.[2] The shoulder was then passively rotated internally or externally until a firm endpoint was felt by a single assessor.[4,7] A total of three trials were obtained for both directions bilaterally and used for descriptive purposes. Angles were recorded by placing a digital inclinometer (Baseline, Fabrication Enterprises Inc,White Plains, New York) firmly against the volar surface of the forearm. Degrees of internal or external rotation were determined as the angle between the volar surface of the arm from the vertical reference position. Total arc range of motion was measured by combining the values for internal and external rotation values.

Ultrasound Measure

Indirect US measurements for humeral torsion were recorded with an 8MHz linear transducer using a GE LOGIQ Book XP (GE Medical Systems, Milwaukee, WI) with the participants supine and shoulder in the same starting position used for range of motion.[5,6,8-11,13-15] The US transducer was placed perpendicular to the proximal humerus in line with the biceps tendon. One assessor with over a year of musculoskeletal US experience obtained all US measures. Assessor 1 rotated the arm until the greater and lesser tuberosities were visible and level through US imaging using a horizontal reference grid (Figure 2).[10,13-15] Assessor 2 calculated the bicipital forearm angle as an indirect measure of humeral torsion by placing the digital inclinometer firmly on the volar surface of the forearm in reference to the starting position.[5] US angles were interpreted and reported with negative angles indicating internal rotation of the humerus and positive values representing external rotation.

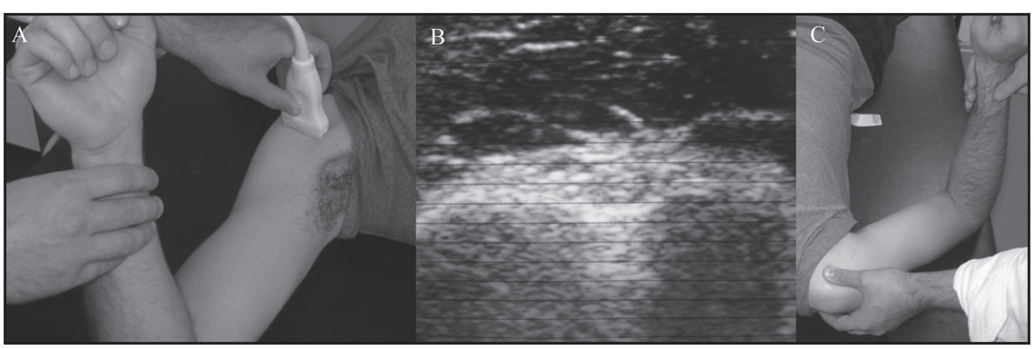

Figure 2. *Transducer placement (A) and reference grid (B) for ultrasound measurement. Palpation placement (C) for clinical examinations*

Bicipital Tuberosity Palpation

Bicipital tuberosity palpation was conducted in two separate positions, both with participants supine on the table (Figure 1a and 1b) by both assessors. The initial shoulder position occurred with the subject supine, and the shoulder positioned in 90 degrees of shoulder abduction and 90 degrees of elbow flexion (Palp90). A single assessor palpated the humeral head on the anterior portion of the deltoid with the thumb, rotating the arm until both the greater and lesser tubercles could be palpated simultaneously (Figure 2). This reference point was referred to as the bicipital tuberosity and used for all palpation measurements. The second assessor then recorded the angle of rotation on the anterior portion of the forearm. A second clinical palpation assessment was recorded using the same palpation technique with the shoulder abducted at approximately 45 degrees of shoulder abduction and elbow flexed at 90 degrees (Palp45).

Horizontal Adduction Test

A modified version of previously reported methods for HADD[10,16] was conducted in the current study with the participants supine on the table by both assessors. A single assessor brought the arm across the chest into HADD with the scapula maintaining contact with the table and humerus positioned at 90 degrees in reference to the table until a firm end point was felt (Figure 1c). Assessors maintained the humerus in a vertical position, and the angle of external rotation was measured by placing the inclinometer on the posterior portion of the forearm and recorded as a positive value away from a vertical reference position.

Statistical analysis

Statistical analyses were administered using SPSS software version 20.0 (SPSS, Inc; Chicago, IL). Within assessor intraclass correlation coefficients ($ICC_{(3,1)}$) with 95% confidence intervals were conducted using a two way mixed model single measure for absolute agreement, while between assessor $ICC_{(2,k)}$ with 95% confidence intervals were administered using a two way random model with average measures and absolute agreement. Standard errors of measurements (SEM) were calculated for all within and between tester variables. US and clinical test data from assessor 1 were normally distributed and assessed using Pearson correlation coefficients. Bland-Altman plots were constructed to display the level of agreement for assessor 1 between each clinical test and the US measure of humeral torsion. ICC's were interpreted with values, greater than .75 as good, or 0-.75 as poor to moderate, and Pearson correlation coefficient relationships with values greater than 0.75 as good to excellent, 0.50 to 0.75 as moderate to good, 0.25-0.50 as fair and values less than 0.25 as little or no relationship.[17]

RESULTS

Thirty subjects (male: 12, female: 18, age: 20 ± 2 yrs, height: 174.24 ± 9.35 cm, mass: 70.53 ± 11.06 kg, body mass index: 23.13 ± 2.47 kg/m^2, years in sport: 9 ± 4 years) completed this study for a total of 60 shoulders assessed for measures of humeral torsion. Sport participation among the current individuals included baseball, softball, tennis and volleyball, and descriptive statistics for all participants can be found in Table 1. Intratester reliability for the US measurement for assessor 1 was good (ICC = 0.907) and intratester reliability for all three clinical measures was greater than 0.769 for both assessors. (Table 2) Intertester reliability measures demonstrated poor to moderate ICC values of 0.256 for the Palp90, 0.419 for the Palp45 degrees and 0.243 for the HADD. Standard error of measure ranged from three to nine degrees between the US and clinical assessments measures. (Table 2)

The bicipital palpation at 90 degrees was the only clinical assessment to be significantly correlated to the US measurements ($r = 0.326$, $p = 0.011$), indicating that as the US angle increased a similar increase for humeral torsion was observed during the bicipital palpation at 90 degrees. (Table 3) Mean differences and limits of agreement using Bland-Altman plots varied for each of the clinical tests when compared to US for assessor 1. (Figures 3-5) Mean differences between clinical measures and US were approximately nine degrees on average with limits of agreement between -32 and 29 for the Palp90, -28 and 38 for the Palp45, and -56 and 20 for the HADD with US measures.

DISCUSSION

The current results show good reliability for within assessor measurements, however between assessor

Table 1. *Subject descriptive information*

Subjects (n=30; 12m/18f)	Means SD	Means SD
Age (years)	20±2	
Height (cm)	174.24±9.35	
Weight (kg)	70.53±11.06	
Body Mass Index (kg/m^2)	23.13±2.47	
Years in sport	9±4	
	Throwing Arm	Non-throwing Arm
IR ROM	64±14	82±14
ER ROM	125±14	113±17
Total arc ROM	189±18	195±18

SD= standard deviation, cm=centimeter, kg = kilogram, m=meter, IR internal rotation, ROM range of motion, ER external rotation

Table 2. *Intraclass correlation coefficients and standard error of measurement for intratester and intertester reliability*

Intratester (n=60)	Assessor 1		Assessor 2	
	ICC (95% CI)	SEM	ICC (95% CI)	SEM
US	0.907 (0.862,0.904)	5		
Palp90	0.857 (0.791,0.907)	4	0.847 (0.778,0.900)	4
Palp45	0.884 (0.827,0.925)	3	0.909 (0.864,0.941)	3
HADD	0.816 (0.735,0.878)	4	0.769 (0.672,0.845)	3
Intertester Reliability	ICC (95% CI)	SEM		
Palp90	0.256 (0,0.529)	9		
Palp45	0.419 (0.057,0.646)	7		
HADD	0.243 (0,0.537)	6		

US – ultrasound, Palp90 – bicipital tuberosity palpation at 90°, Palp45 – bicipital palpation at 45°, HADD – horizontal adduction, ICC – intraclass correlation coefficient, 95%CI – 95% confidence interval, SEM – standard error of measurement

Table 3. *Pearson correlation coefficients between ultrasound and clinical assessments*

	Correlation Coefficient	p-value
Palpation at 90°	0.326*	0.011
Palpation at 45°	0.171	0.192
Horizontal Adduction	-0.218	0.095

* indicates significance at p<.05

measurements were poor to moderate for each clinical assessment. (Table 2) Of the three clinical assessments by assessor 1, the Palp90 had a significant but fair relationship with the US measures. These findings only partially supported the authors' hypothesis, indicating that the use of clinical measures may be repeatable for an individual assessor, but may not be reproducible between multiple assessors or provide similar measurements when compared to US imaging. Thus, current findings indicate that although each assessor is able to obtain a measure consistently, they may not be obtaining the correct measure of humeral torsion with the clinical assessments.

US measurements have previously been found to be both a reliable measurement,[6,10] and are related to CT humeral torsion measures.[13] Precision of US humeral torsion measurements may be improved with the use of grid markings over the US screen in order to ensure the bicipital tuberosities are level during the ultrasound imaging[13-15] The current findings observed an ICC of 0.907 with a SEM of five degrees for US measures using a marked grid on the US screen. While the current US measure was found to be reliable across multiple trials for a single assessor, the use of a bubble level may improve the overall precision of the US measure by maintaining a standard angle for the transducer head during all measurements.[6,9,11,13-15] Advantages for the use of US for assessing humeral torsion are the reduction of radiology exposure experienced by the athlete and the quickness and ease of administration.[6,13]

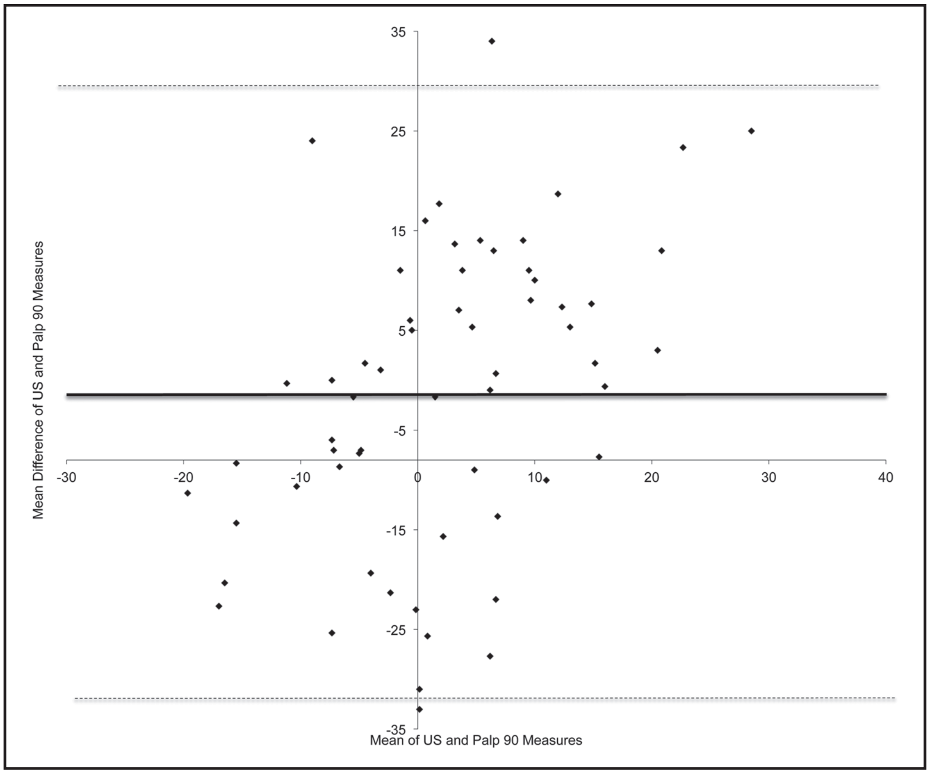

Figure 3. *Figure 1 Bland-Altman plot comparison between ultrasound and bicipital palpation at 90 degrees*

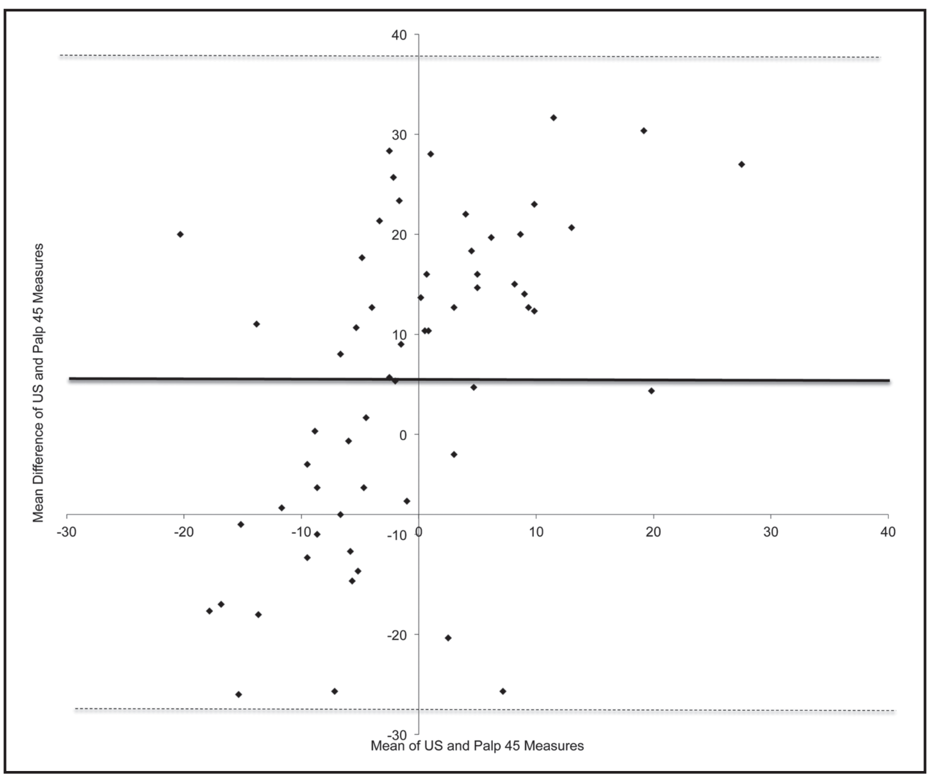

Figure 4. *Figure 2 Bland-Altman plot comparison between ultrasound and bicipital palpation at 45 degrees*

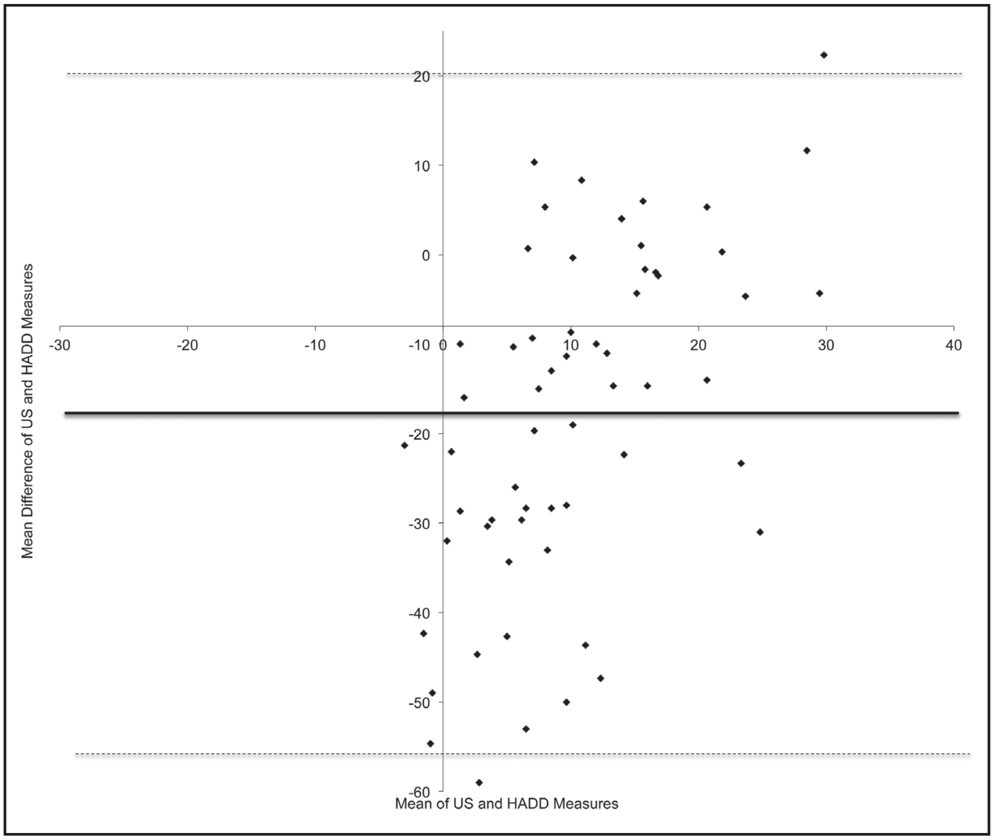

Figure 5. *Figure 3 Bland-Altman plot comparisons between ultrasound and horizontal adduction*

The results of this study indicate that independently, assessors can locate a consistent clinical measure through three clinical assessments that might indirectly measure humeral torsion (Table 2). However, the reliability between assessors was poor, similar to a previous finding indicating that clinical palpation methods were not reliable between multiple assessors.[6] Even though the current findings indicate that intratester reliability was high for each assessor, the clinical utility of these measures is cautioned as multiple clinicians may obtain different measurements. Increasing internal validity of the three assessments among clinicians might be achieved through the addition of specific standardized testing instructions, additional experience with anatomical palpation methods or limiting muscle tension of the shoulder during abduction by placing the shoulder in a more relaxed position.[15]

Little or fair relationships were currently reported between the US measure and the three clinical assessments for assessor one (Table 3). Additionally Bland-Altman plots between US and clinical assessments had large 95% limits of agreement (Figures 3-5) indicating poor relationships between the measures. These findings indicate that relationships between US and palpation methods may be lower than previously reported,[15] and may be a result that the previous findings occurred with the arm at the side rather than abducted at either 90 degrees or 45 degrees. The palpation methods used in the current study were chosen to closely resemble the US testing position as the authors' hypothesized that similar testing positions would be correlated between the two measurement techniques. Interestingly the authors observed the highest agreement between assessors occurred with the shoulder abducted at 45 degrees, however trends were noted in all measures. These trends indicate that the ability to measure humeral torsion between US and clinical assessments may be different depending on if the mean difference of the measures is low or high. Lower averages between the two measures would indicate that the indirect US measure and the clinical test produced similar values using either test, while larger mean differences indicate inconsistency between the two measures. The current findings indicate that as the mean differences between the two measure increases, the closer they get to the 95% limits of agreement. This could result during clinical palpation assessments among individuals with extreme levels of humeral torsion resulting in increased soft tissue tension on the shoulder during increased internal or external rotation. Therefore, methods that place less tension on the shoulder musculature during the performance of the test may provide a better position to identify the bicipital tuberosities between assessors[15] and may increase reliability of humeral torsion measures between different assessors. Although the authors observed fair reliability between assessors during the Palp45 measure, the Palp90 measure was the only assessment that correlated with US measures. Even though this measure was significantly correlated with the US measure, the magnitude was only fair and may indicate that other factors influence the angles between the two measures, or that the palpation method is not a true indirect measure of humeral torsion. Therefore, current assessment techniques may need to be improved upon or used in conjunction with currently validated measures when assessing humeral torsion.

This was the first study to attempt to use the HADD test to measure humeral torsion. The HADD test does not require palpation of anatomical structures, and measures the resting external rotation of the shoulder in the HADD position. Therefore, angular differences with the arm in this position may reflect the amount of osseous rotation at the shoulder, with larger angles of external rotation indicating greater humeral torsion values. While the individual assessor intratester ICCs for the HADD test were good, the current findings showed poor measures between assessors for the HADD test. This may occur if an assessor fails to stabilize the scapula on the table, if the testing arm rotates during HADD or if a stretch is performed on the shoulder. Additionally, the findings from the current study indicated that HADD measures are not associated with indirect measures of humeral torsion through US measures. (Table 3) Previous applications using the HADD test include stabilizing the scapula in a retracted position with a hand.[10,16] The modified HADD test in the current study originally stabilized the scapula against the table, but did not manually support the scapula throughout testing. As a result, some scapular movement could have occurred during testing. Although all within tester reliability measures were high, the HADD test had the lowest ICC values for each assessor. Therefore, the implementation of the HADD test would need to be improved or standardized to increase reliability and validity of this measure.

Implementing clinical assessments for humeral torsion has been recommended as part of the clinical examination of the shoulder complex.[15] Readily accessible methods for measuring humeral torsion could potentially identify individuals at risk for injury. Humeral torsion measures have been associated with upper extremity injuries[11] of both the shoulder complex[1,12] and the elbow.[12,14] Reduced bilateral humeral torsion has been found in individuals with both chronic shoulder injury[1] while increased bilateral measures have been associated with elbow injuries.[14] Findings from previous studies suggest the potential for reduced non-dominant arm retroversion to influence injury[11] and relationships between humeral torsion measures and injury severity.[12] Implementing clinical humeral torsion assessments could potentially identify athletes at risk for injury, or provide additional information regarding the association between humeral torsion levels and injury in the future. These findings could lead to injury risk awareness or modifications to activities, sport participation, or sport positions in individuals at increased risk for shoulder injury. However identifying these individuals is dependent on the validity of the testing measure. In the current study, only one of the three clinical assessments was fairly correlated with US therefore indicating that clinical assessments of humeral torsion need to still be validated before they are implemented into the clinical setting. These findings are in contrast with previous findings assessing relationships between palpation of the bicipital tuberosities with the arm at the side compared to US measures.[15] Therefore, future studies should focus on the positioning of the shoulder and how these measures relate to previously validated measures of humeral torsion.

Limitations of the current study include experience of the assessors with both US and the clinical assessments. One assessor with over a year of musculoskeletal US experience, compared humeral torsion using both US and clinical assessments. Therefore we were unable to assess the intertester reliability of the US measures between the two assessors and determine the strength of relationships between US and clinical tests for the second assessor in the current study. Even though the assessor in the current study had experience with the US measure used in this study, additional training focusing on the anatomical structures of the shoulder may be necessary for clinicians.[15] Although palpation and clinical assessments are common skills of health care professionals, additional training in the direct palpation or HADD assessments may result in improved reliability between assessors, as previous reported palpation methods identified that clinicians were able to improve their measures with experience.[15] Therefore, clinicians with more experience in both the application of the US and clinical assessments may find better relationships between the two measures. The decision to compare US to palpation methods may be another limiting factor, as CT directly measures humeral torsion and has previously been reported to be the gold standard.[13] However, direct comparisons between CT and US measures have found results to be highly correlated.[13] These findings along with the portability of the US, reduced exposure to radiation, and reduced testing time influenced the decision to use US in the current study. An additional factor that the authors' did not control in the current study for were both muscle and subcutaneous tissue. Increased thickness of either of these two measures could impede the ability to accurately palpate anatomical structures,[15] indicating that other measures may be more beneficial to assess humeral torsion. The current palpation methods were conducted with the shoulder positioned at both 90 and 45 degrees of shoulder abduction compared to the arm at the side of the body.[15] Although, the current positioning of the clinical palpation at 90 degrees of abduction was identical to the US method, the position of the shoulder may limit the ability to properly identify the bicipital tuberosities due to the static strain placed on the deltoid in this position. Palpation of the humerus in a resting state with the arm to the side of the body, could allow for increased anatomical identification through palpation methods.

CONCLUSION

The current findings indicate that individual assessors are able to consistently obtain US, bicipital palpation, and HADD measures at the shoulder, but these measures may differ between assessors. Only a fair relation between the Palp90 existed with US measures, indicating the while individual reliability of the studied test is high, it may not be a valid measure of humeral torsion. Improved testing procedures or guidelines may be necessary to increase both between tester reliability and consistency with previously reported and validated measures for assessing humeral torsion.

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